Large-scale shear layers affect the scaling exponents for dissipation and enstrophy beyond $Re_\lambda \approx 250$

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Direct numerical simulations of homogenous isotropic turbulence up to $Re_\lambda = 1445$ show that the Reynolds number scaling exponents are different for the enstrophy and the dissipation rate extrema and, moreover, that these exponents depend on the Reynolds number. A similar Reynolds number dependence of the scaling exponents is observed for the moments of the dissipation rate, but not for the moments of the enstrophy (figure 1). Significant developments in the exponents occur beyond $Re_\lambda \approx 250$, which coincides with the appearance of large-scale shear layers in the flow[1,2]. Here, Re_λ is the Taylor based Reynolds number. A model for the probability density functions (PDFs) of the enstrophy and dissipate rate is presented, which is an extension of our existing model[3] and is based on the mentioned development of large-scale layer regions within the flow. This model is able to capture the observed Reynolds number dependencies of the scaling exponents, contrary to the existing theories which yield constant exponents independent of the Reynolds number. It suggests that the large-scale shear layers are vital for understanding the scaling of the moments and the extrema. Additionally, the present findings provide further quantitative evidence for significant small-scale structural developments beyond $Re_\lambda \approx 250$ [2,4,5].

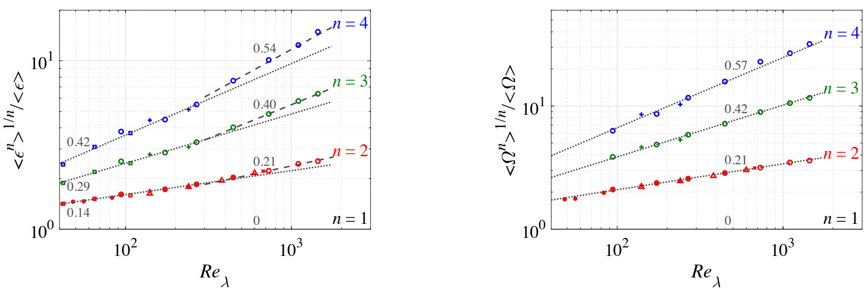

Figure 1: Moments of the dissipation (left) and the enstrophy (right) raised to the power $1/n$. Symbols show DNS data from (*) Kerr (1985), (squares) Schumacher, Sreenivasan & Yakhot (2007), (+) Donzis, Yeung & Sreenivasan (2008), (Δ) Yeung, Donzis & Sreenivasan (2012) and (o) present. The dotted and dashed lines present local power law fits of the data. The locally fitted exponents are indicated.

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